Multiple Chamber Aligned in Parallel Speaker System (MCAPSS)

Basic Concepts

Advanced Loudspeaker Enclosure

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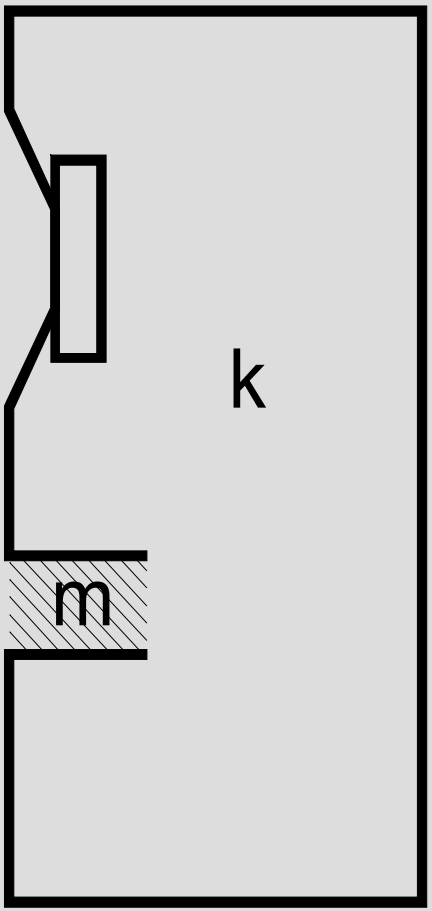
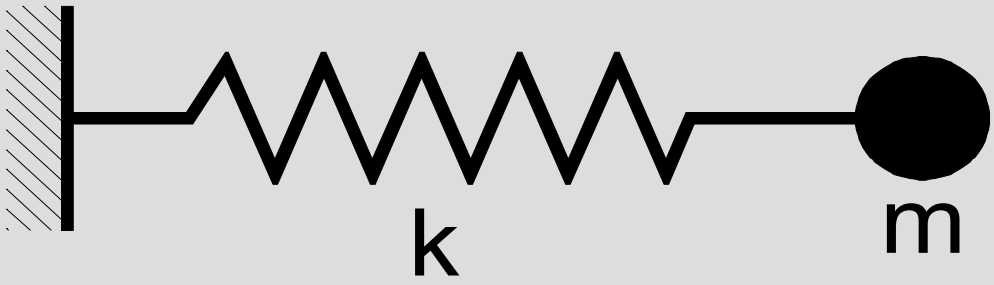
Document Number : MCAP002E

Traditional Approaches
Bass-Reflex Architecture



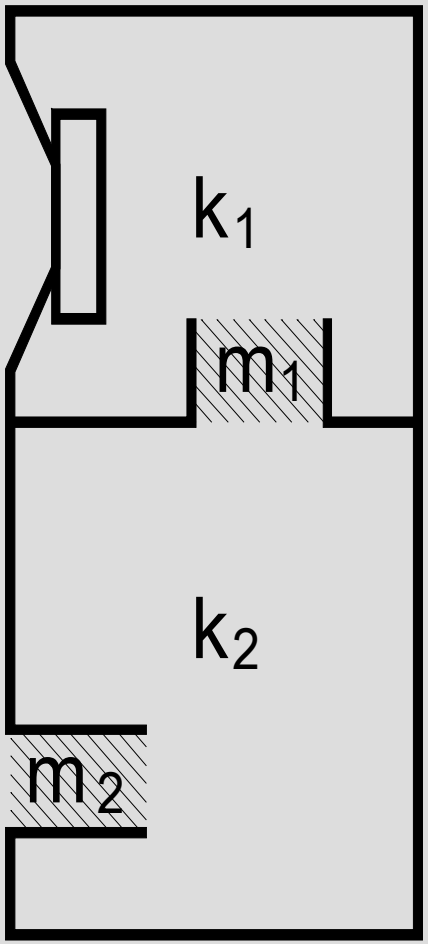


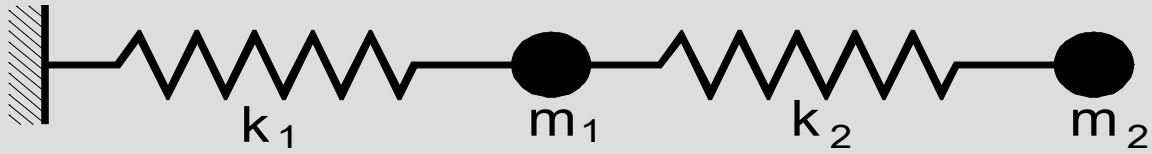
Single Bass Reflex system has just ONE Characteristic Frequency

$$f_D = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Bass-reflex architecture is an application of Helmholtz's cavity resonator

Traditional Approaches
Double-Bass-Reflex Architecture





Double Bass Reflex system has TWO Characteristic Frequencies.

$$f_D = \frac{1}{2\pi}\sqrt{\frac{k_{11}m_2 + k_{22}m_1 \pm \sqrt{(k_{11}m_2 + k_{22}m_1)^2 - 4m_1m_2(k_{11}k_{22} - k_{12}k_{21})}}{2m_1m_2}}$$

See Appendix-A of "Equations to calculate characteristic frequencies of Multiple Chamber Aligned Speaker System (MCAPSS)" by Shigeru Suzuki.

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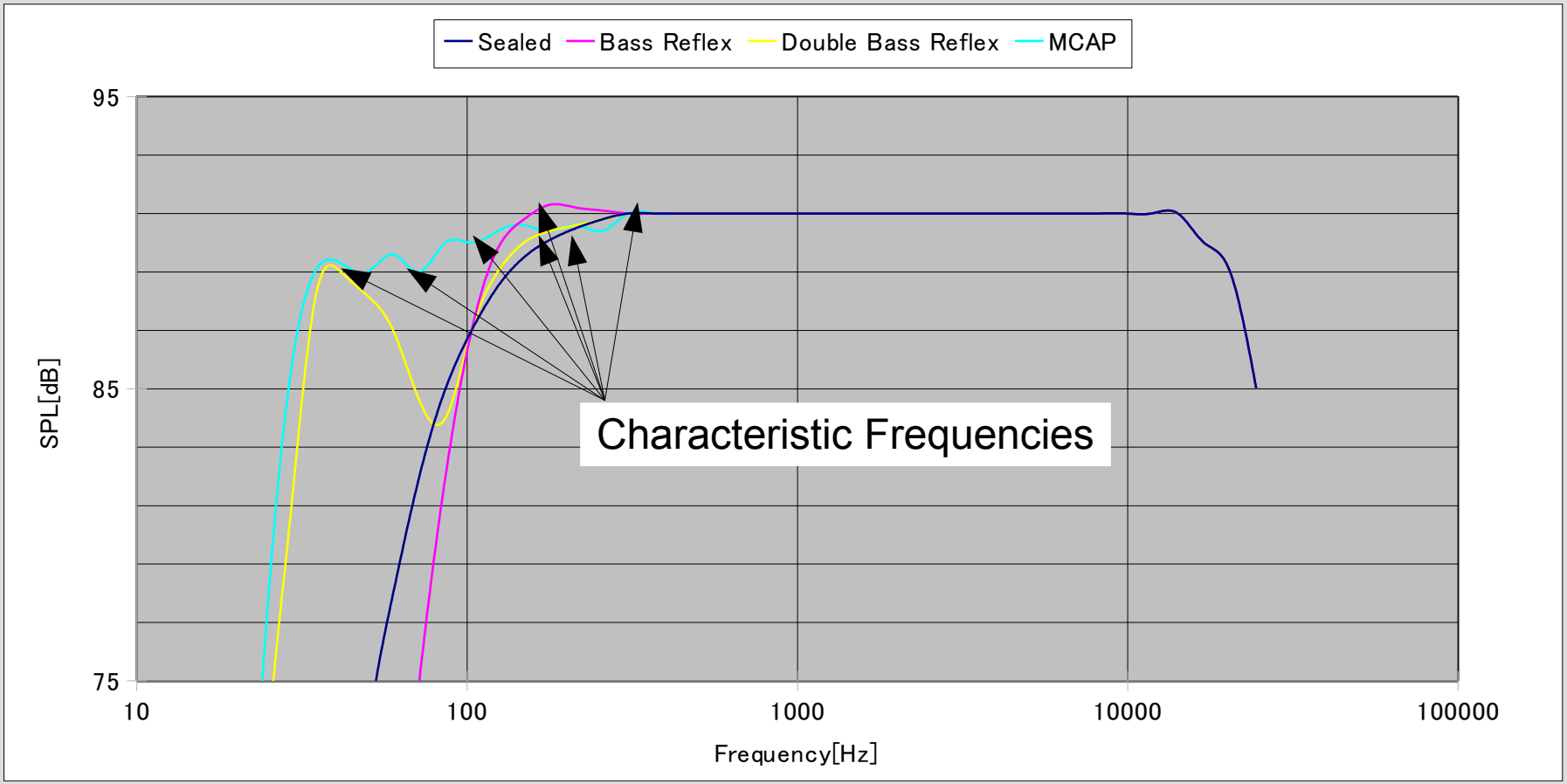
Technical Target of MCAPSS

- Improve frequency response over low range (below f_0 of speaker unit)
- Let this architecture suitable not only for woofer drivers but also for full-range speaker drivers.
- Make Speaker Enclosure size smaller as much as possible compared with existing equivalent systems.
- Develop calculation method so that everyone could design one's own.

Advantages of MCAPSS

- MCAPSS architecture has multiple characteristic frequency. The number of characteristic frequencies is theoretically unlimited.
- MCAPSS architecture generates lower frequency than f_o at considerably high sound pressure level.
- MCAPSS architecture requires smaller enclosure than existing equivalent systems.
- MCAPSS is not only suitable for woofer drivers but also full-range drivers . Full-range drivers are free from electrical network circuits so that they are advantageous.

Frequency Response
MCAPSS vs. Traditional Approaches

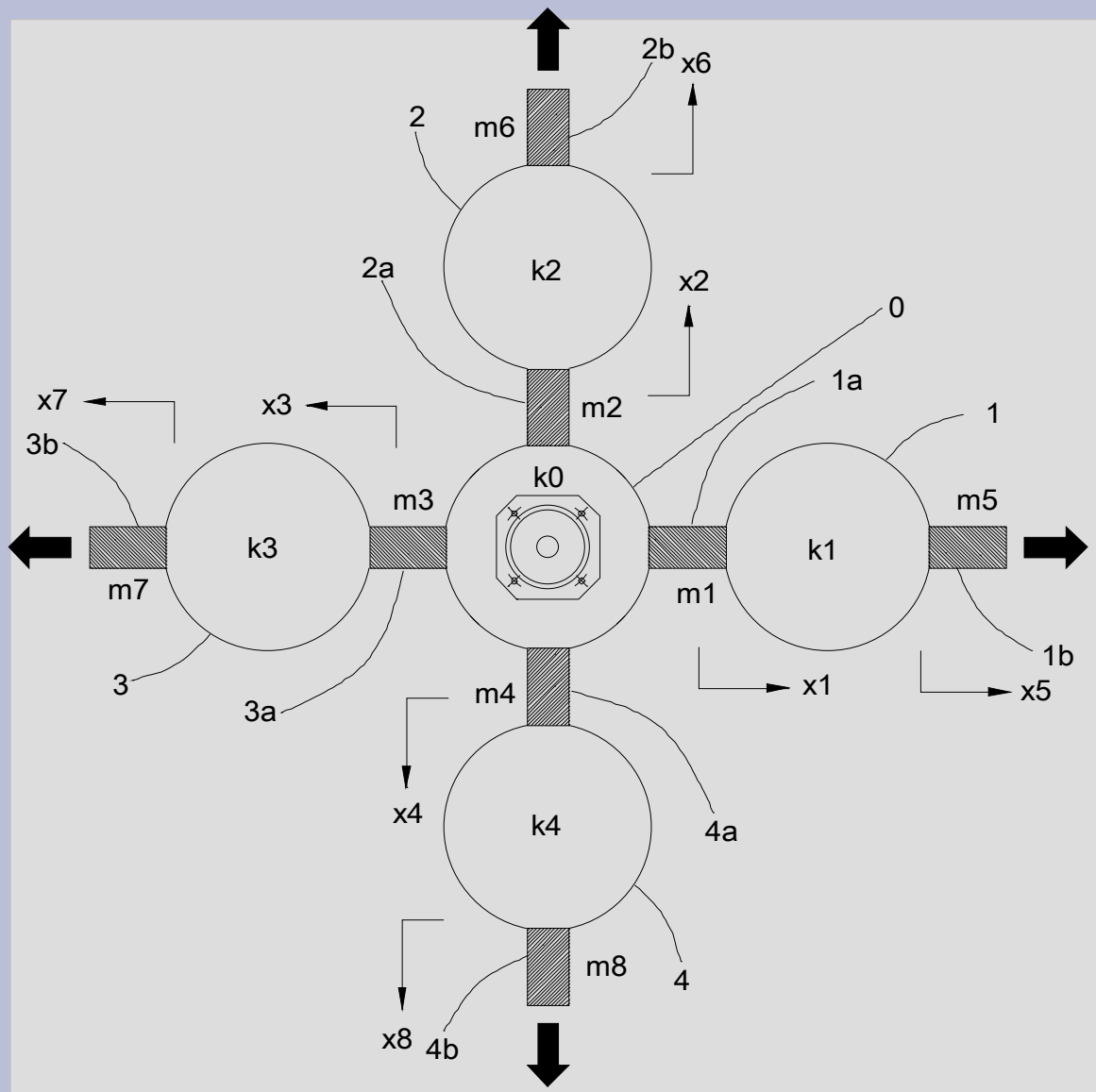


MCAPSS has 4 or more characteristic frequencies (depends on number of chambers and ducts), while double-bass-reflex has 2 and single-bass-reflex has one.
Multiple characteristic frequency realizes improved response in low frequently region.
Note: This is just conceptual figure to explain difference among different systems.

Technical Feature of MCAPSS

- MCAPSS stands for *Multiple-Chamber Aligned in Parallel Speaker System*.
- MCAPSS is designed to boost multiple-characteristic frequency.
- MCAPSS consists of main chamber where speaker driver is installed, sub-chambers, and ducts.
- Each sub-chamber is connected to main chamber through inter-chamber duct.
- Some of (typically, all) sub-chambers have open-air duct.

How MCAPSS works
Schematic: Number of Sub chambers=4



0: Main chamber
1-4 : Sub-chamber

m1 - m8: mass of air that is involved in each duct
k0 : reference spring constant for speaker cone
k1 -k4 : equivalent spring constant for each duct
x1 - x8 : displacement of mass of air

Note: Number of sub-chambers is theoretically unlimited.
If number of sub-chambers is one, it is identical to traditional double-bass-reflex architecture.

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Equations of Motion of MCAPSS

Equations of Motion : Free Vibration

$$\begin{cases} m_j \ddot{x}_j + k_0 r_j \sum_{i=1}^{N} r_i x_i + k_j r_j \left(r_j x_j - r_{j+N} x_{j+N} \right) = 0 \\ m_{j+N} \ddot{x}_{j+N} + k_j r_j \left(r_{j+N} x_{j+N} - r_j x_j \right) = 0 \end{cases}$$

m_j: mass of air involved in each duct
N: number of sub-chambers
k_0: reference spring constant of base chamber
k_1-k_N : spring constant of each sub chamber for reference cross-sectional area
r_j : ratio of cross sectional area divided by reference area
x_j : displacement of air mass in each duct

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Equation of Motion: Matrix Form

Equation of motion of free vibration can be expressed in matrix form.

$$\mathbf{M}\ddot{\mathbf{X}} + \mathbf{K}\mathbf{X} = \mathbf{0}$$

M: Mass Matrix
K: Stiffness Matrix
X: Displacement Vector

Eigen Value Problem

$$\left|\mathbf{K} - \lambda \mathbf{M}\right| = 0$$

λ : Eigen Value

Solving Equations of MCAPSS

Refer to another document

1. Determine number of sub-chambers
2. Determine principal dimensions (size of chambers, ducts)
3. Develop equations of motion of your model
4. Calculate mass-matrix and stiffness-matrix
5. Solve Eigen Value Problem using a computer program (described in another document).

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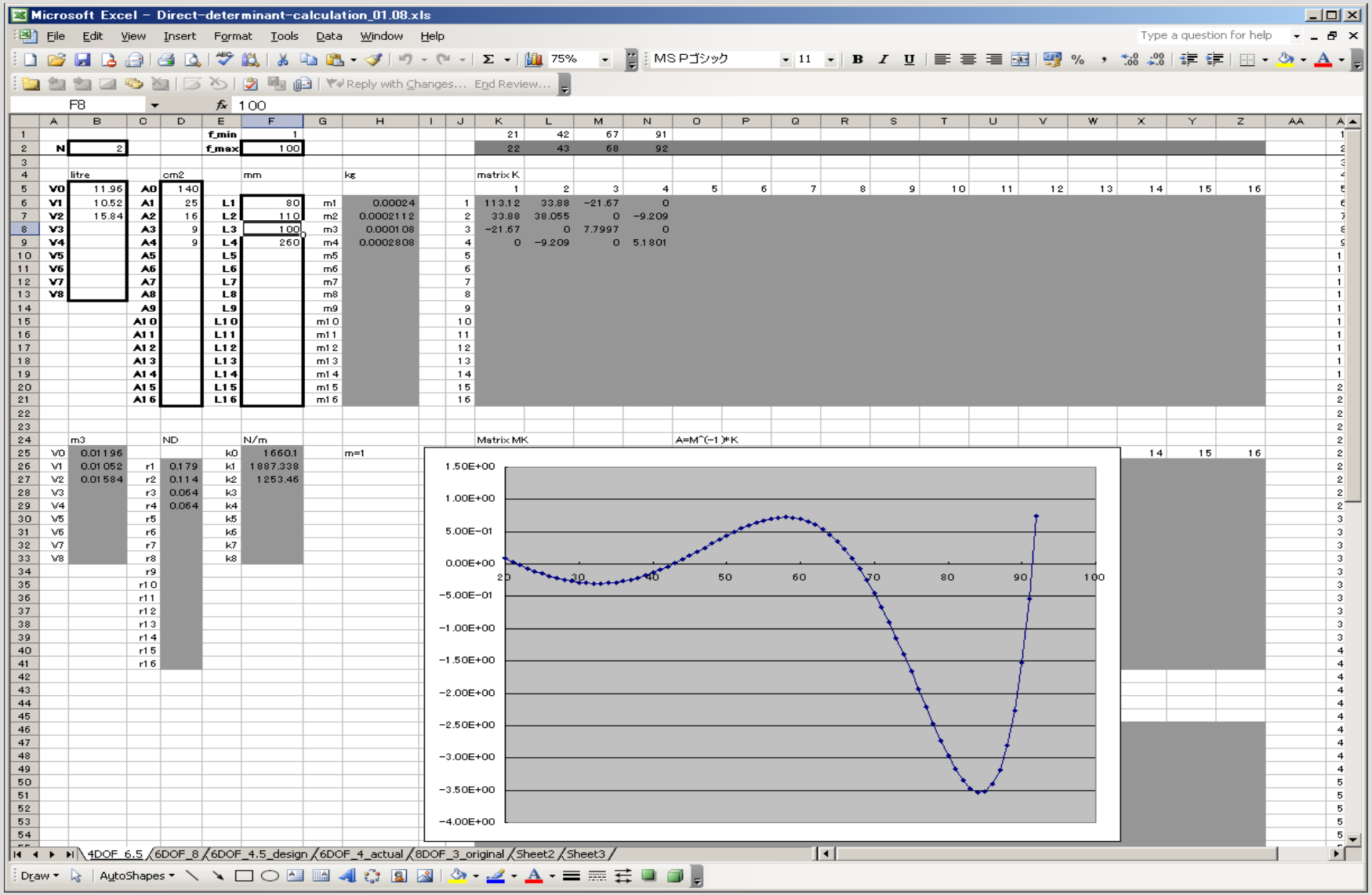
Solving Equations of MCAPSS

Calculation Window (Example)



Expected Q & A (1) General

QUESTIONS	ANSWERS
• Do I like MCAPSS sound?	• *It is recommended for those who like full-range system's sounds, but not recommended for those who prefer multiple-way systems rather than full-range systems.*
• Is designing MCAPSS difficult for me?	• *It may be difficult if you are not good at mathematics. Knowledge level of MS in Engineering may be required.*
• Do you have examples of MCAPSS?	• *Yes. I have already made six models. Some of them will be uploaded to this web page.*
• Is MCAPSS good for high fidelity system?	• *I believe YES. One advantage of MCAPSS is it is good for full-range drivers.*
• Is it difficult to assemble MCAPSS?	• *It may be difficult for beginners.*

Expected Q & A (2) General

QUESTIONS	***ANSWERS***
• I have difficulty to calculate and design MCAPSS. May I ask you for more details?	• *Yes, I would try to help you as much as possible. Please do not hesitate to contact me.*
• Where can I buy MCAPSS?	• *Any MCAPSS is not sold right now. There is no manufacturer. I wish I could, but I have no fund to found a company.*
• Where can I hear sound of MCAPSS?	• *There is nowhere you can hear sound of MCAPSS except my home. You may write to me if you really want to hear them. My home is located in Tokyo, Japan.*
• Do I need to pay for the patent.	• *Patent application was submitted in 2007, but it has not yet become a right. Even though patented, it does not affect non-commercial personal use.*

Expected Q & A (3) Technical

QUESTIONS	ANSWERS
• What is the recommended number of sub-chambers?	• *It must be at least 2. N=2, 3, or 4 will be suitable for practical reasons.*
• What characteristic frequency should be targeted?	• *From my experience, lowest characteristic frequency should be 50Hz for 3" drivers, 40Hz for 4" drivers, and 20Hz – 30Hz for 6.5" and bigger drivers. Highest characteristic frequency may be determined based on driver's response curve.*
• How can I determine size of ducts and volume of each chamber?	• *You may begin with defining volume of chambers. Chamber's size depends on practical constraint. I suggest that summation of cross sectional area of each inter-chamber duct does not exceed ½ of driver's effective area (a_0). Cross sectional area of open-air duct should be equal or even smaller than of inter-chamber duct. Then calculate characteristic frequencies. Parameter should be lengths of ducts.*

Expected Q & A (4) Technical

QUESTIONS	***ANSWERS***
• Response in low frequency region seems not enough. What can I do?	• *MCAPSS generates lowest characteristic frequency, so you may boost low frequency using tone control. Bass-reflex system cannot boost lower than f_D; it is true to MCASPS, but MCAPSS has lower f_D, thus using tone control is very effective.*
• Which drivers should be suitable for MCAPSS?	• *Considerably powerful full-range drives are recommended. I suggest 3" drivers of Tangband: W3-316 is most recommended. If you like Fostex, I suggest FE126E, FE166E, FE206E, FF125K, FF165K, and FF225K; however, any driver can be used as you prefer.*

Expected Q & A (5) Technical

QUESTIONS	***ANSWERS***
• May I think that MCAPSS is competed technology?	• *MCAPSS is proven technology, yet it is not complete. Any technology is perfect. We have to improve applications everyday.*
• How can you complete MCAPSS technology?	• *I will try to design, assemble and test as many models as possible, but cannot make enough. I would be the most happy, if you want to work with me to help developing MCAPSS. One purpose of publishing this document is to find a partner. My contact email address is shown in the web page.*

Summary

- *MCAPSS is an application of cavity resonator speaker system with multiple characteristic frequency.*
- *Equations and solution were proposed.*
- *MCAPSS is suitable not only for woofer drivers but also full-range drivers.*
- *I would be the most happy if you become interested in MCAPSS. - Thank you.*